HPS™ Products Series 325 Moducell®

Pirani Vacuum
Sensor/Transducer

OPERATION AND MAINTENANCE MANUAL

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Pirani Vacuum Sensor / Transducer

Part #

Serial # _ _ _ _ _ _ _

Please fill in these numbers and have them readily available when calling for service or additional information.
(The part number can be found on youpacking slip, and both the part number and serial number are located on the bottom side of the housing.)

For more information or literature, contact:

MKS Instruments, Inc. HPS™ Products, Inc.
5330 Sterling Drive
Boulder, CO 80301 USA

Phone: 303-449-9861
800-345-1967

Fax: 303-442-6880

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Package Contents

Please be sure that your Series 325 Moducell package contains these items:

- MODUCELL® Sensor unit (integrated tube and electronics)
- male, 9-pin, subminiature D (D-sub) connector
- HPS™ Products Series 325 MODUCELL® Pirani Vacuum Sensor/ Transducer User's Manual

☎ f any items are missing from the package, call HPS™ Customer Service at 1-303-449-9861 or 1-800-345-1967.

If the unit has been damaged in shipping, notify the carrier immediately. Keep all shipping materials and packaging for claim verification.

Symbols Used in this Manual

The first two symbols below, that may be located on your Series 325 Moducell®, identify critical safety concerns. They are used throughout this manual to further define the safety concerns associated with the product.

The last tow symbols identify other information in this manual that is essential or useful in achieving optimal performance from the Series 325 Moducell®.

CAUTION: Rick of electrical shock.

CAUTION: Refer to manual. Failure to read message could result in personal injury or serious damage to the equipment or both.

Failure to read message could result in damage to the equipment

Calls attention to important procedures, practices, or conditions.

Safety Precautions

WARNING: Do not use the MODUCELL® with combustible gases or with flammable gases which react in air.

If the control circuit fails, the Sensor wire could ignite the gas mixture. With some mixtures, an exothermic catalytic reaction could occur at the Sensor wire, igniting the gas.

WARNING: Prevent an explosion or personal injury. Take precautions against overpressure during system backfill.

When backfilling, keep pressure indications at or below 100 Torr for the MODUCELL®. Above 100 Torr, the system pressure may be much higher than indicated. This could lead to a dangerous overpressure. In a system which is filled using a pressurized source, install a safety relief valve or burst disc to safely limit pressure.

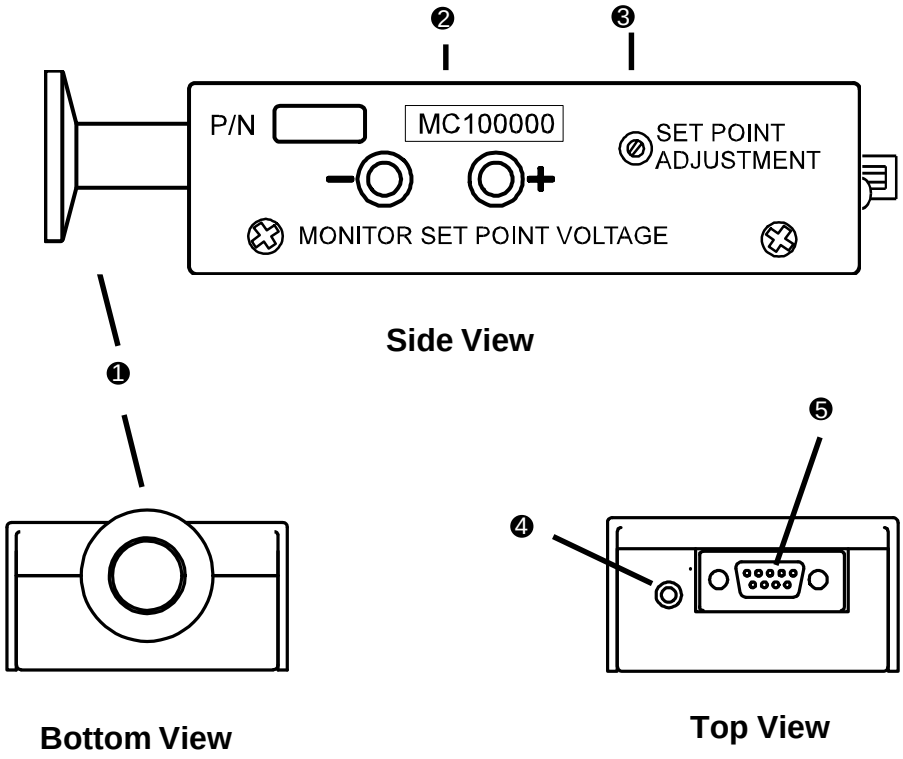
If the MODUCELL® is calibrated for air/nitrogen, the measured voltage may vary considerably as a function of true pressure for other gases. Refer to page 12 for use with other gases.

Specifications

Measuring Range	1.0×10^{-3} to 100 Torr 1.3×10^{-3} to $1.3 \times 10^{+2}$ mbar 1.3×10^{-1} to $1.3 \times 10^{+4}$ Pa
Useful Set Point Range	5.0×10^{-3} to 30 Torr 6.6×10^{-3} to $4.0 \times 10^{+1}$ mbar 6.6×10^{-1} to $4.0 \times 10^{+3}$ Pa
Calibration Gas	Air/nitrogen
Operating Temperature Range	0 to 50C (32 to 122F)
Maximum Bakeout Temperature	85C (185F)
Power Requirements	15 VDC (11.4 to 15.8 V), 0.175 A or 24 VDC (22.0 to 26.0 V), 0.175 A
Output Voltage	0.2 to 3.25 VDC, 1 kW (max) impedance
Relay Contact Rating	2A @ 28 VDC 2A @ 50 VAC, SPDT
Relay Response**	15 to 150 msec
Installation Orientation	Any
Internal Volume	Less than 0.49 $in.^3$ (8.0 cm^3)
Materials Exposed to Vacuum	304 stainless steel, platinum, alumina ceramic, silver brazing alloy, nickel 200
Flanges/Interfacing	KF 16 8 VCR®- F (") 1/8" NPT-M with " compression fitting 1 1/3" CF 2 æ" CF ÿ15 mm x 30 mm tubing ÿ18 mm x 30 mm tubing
Connectors	Female, 9-pin D-sub and tip jacks
Electronic Casing	Aluminum
Casing Dimensions (W x D x H)	2 3/8" x 1º" x 4 3/8" (60.3 mm x 31.8 mm x 111.1 mm)
Weight (with KF Flange)	0.5 lb (0.23 kg)

**The fast response (15 msec) is for a quick pressure rise to atmosphere, and the slower response (150 msec) is for smaller pressure changes. Special circuitry allows for this dual response.

Design and/or specifications subject to change without notice.



❶ **Sensor Vacuum Port**
❷ **Set Point Voltage Tip Jacks**
❸ **Set Point Adjustment**
❹ **Potentiometer**
❺ **LED Set Point Indicator**
Female, 9-pin D-sub Port

Typical Applications for the MODUCELL®

- ***Measuring foreline and roughing pressures*** generated by mechanical vacuum pumps
- ***Controlling valves and pumps*** to automate system pump down using the relay set point
- ***Sensing abnormal pressure*** and taking appropriate security measures using the relay set point
- ***Controlling system pressure*** using the analog output as input to an automatic pressure controller
- ***Starting or stopping system processes*** using the relay set point
- ***Activating high vacuum sensors*** in their operating range

About the HPS™ Products Series 325 MODUCELL®

The Series 325 MODUCELL® Transducer is a compact, modular Pirani vacuum sensor with an integrated electronic control circuit. Intended as a vacuum control element, it contains a relay set point that allows it to be used as a self-contained vacuum relay switch.

The MODUCELL®ís simple modular design, high reliability, and low cost make it especially attractive to OEM equipment manufacturers. It has an integral sensor tube with the vacuum port mounted axially and is available in several models to accommodate various standard vacuum connections and power sources.

The MODUCELL® is designed for process applications which require pressure control in the range of 10^{-3} to 100 Torr. Its rapid response and wide measurement range make it ideal for a wide array of uses and provide the equipment designer with maximum flexibility. Because it can operate autonomously or as a part of a control system, it is adaptable to several roles, including control, monitor, alarm, and safety functions. For the many uses where specific actions must be taken at a particular point within a vacuum range, it provides many advantages.

The MODUCELL® features one relay for process control, and the relay set point can be adjusted using a built-in potentiometer. An LED indicates the status of the set point relay.

The basic unit does not incorporate a readout and is generally intended to be installed out of sight; values for monitoring pressure and establishing set points are read with a standard digital voltmeter or analog-to-digital (A/D) converter and computer.

Installing the MODUCELL®

Location

Locate the Sensor where it can measure chamber or manifold pressure. Installing it away from pumps and gas sources gives the most representative values. Place the Sensor where vibration is minimal.

Contamination

The location and orientation of the Sensor should be such that sources of contamination which might affect the tube element are avoided. For example, if the sensor is installed directly above a roughing pump in the system, oil vapor could contaminate the Sensorís filament wire and cause the emissivity and calibration to shift.

Installing the Sensor with the vacuum port facing downward is most desirable since it reduces particulates and liquids falling or flowing into the Sensor. If particulates in the system are common, it is necessary to keep them from entering the Sensor using a screen or porous filter at the port. An HPS™ centering ring with a screen, part #100318601, is useful.

Orientation

The MODUCELL® was designed to minimize convection so that operation is possible in any position without compromising accuracy. The Sensor is factory calibrated with the tube vertical and the vacuum port down. Calibration of the unit with the Sensor in any orientation will not affect accuracy at pressures below 100 Torr.

Convection is an effective heat transfer process only at pressures above approximately 400 Torr of nitrogen. In the MODUCELL®, the residual convection effect makes a negligible difference in the pressure indication between a horizontal and a vertical sensor tube at atmospheric pressure.

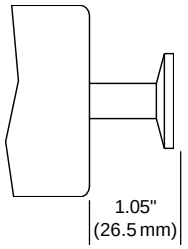
Venting to Atmosphere

Sudden venting of the Sensor at its port can greatly stress the sensor physically and risk damaging its fine heated wire. To avoid damage to the Sensor, vent the vacuum system to atmosphere ***before*** removing it.

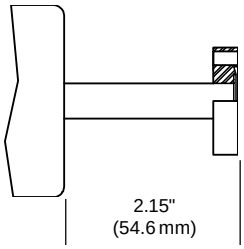
Vacuum Connection

The MODUCELL® is available with any of the standard vacuum connections shown on this page.

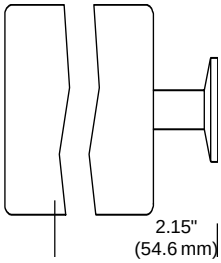
The KF 16 connection requires no special mounting precautions, except where a screen is needed.



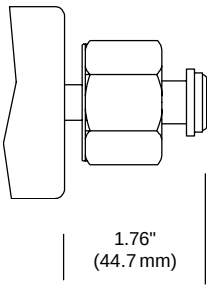
KF 16



1 1/3" CF



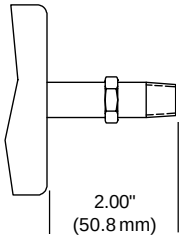
2æ" CF



8 VCR Æ- F (")

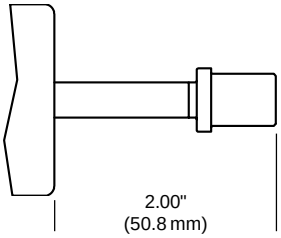
When fitting the MODUCELL® with the 1/8" NPT-M thread, ***do not*** use the case for tightening; the Sensor's tube has been fitted with 9/16" hex flats for tightening. A single wrap of Teflon Æ tape should be used on the threads of the tube to ensure a leak-free seal.

This Sensor can also use a " O-ring compression seal acting on the tubing above the thread, ***but the O-ring seal cannot be used for positive pressure applications***.



1/8" NPT with " compression seal

CAUTION: A solid electrical connection between the sensor tube and the grounded vacuum system must be used to shield the tube element from external power sources. In applications where the system may be exposed to large voltage fluctuations, a centering ring (HPS™ part # 100318601) with a screen should be installed, and the screen and tube then grounded.



– 15 x 30 mm tubing
– 18 x 30 mm tubing

Electrical Connection

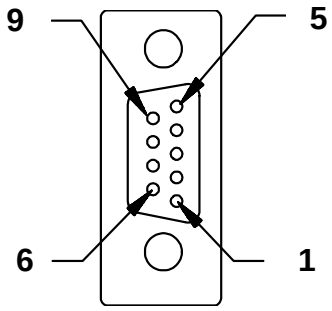
A user-supplied cable is connected to the MODUCELL® using a mating, 9-pin D-sub connector with strain reliefs to ensure proper electrical connection and to reduce stress on the connectors.

Input/Output Wiring

The following chart and the figure at the right identify the pins in the MODUCELL® 9-pin D-sub connector. The user can make a cable using the information from this chart.

The **power supply input** may range from 12 to 15 VDC (or 22 to 26 VDC). The positive side (+) of the power supply is connected to pin 3 and the minus side (-) is connected to pin 4 of the D-sub connector. ***Damage will occur if the polarity of the power supply input is reversed.***

Pin	Description
1	Set point relay ñ normally open contact
2	Set point relay ñ normally closed contact
3	Power supply input (+)
4	Power supply input (-)
5	Analog output voltage (+)
6	Set point relay ñ common
7	Set point relay ñ disable
8	Analog output voltage (-)
9	Set point relay output voltage



Female, 9-pin,

D-sub connector

The **ground connection** to the **set point relay** in the MODUCELL® is pin 7 of the D-sub connector. If pin 7 is left open, then the MODUCELL®ís set point relay is disabled. The set point relay may also be disabled by setting the set point voltage below 200 mV. Any switching mechanism used to control this line must be capable of handling 50 mA at 15 V (or 30 mA at 24 V).

Do not ground pin 7 to pin 4. Doing this will cause a sudden voltage drop on the ground wire, resulting in a large transient in the analog output voltage. Pin 7 must be grounded at the power supply.

The **differential analog outputs** are pin 5 (+) and pin 8 (-). They can be connected to a differential input voltmeter or an A/D converter in a system controller.

Note: Do not connect the (-) side of the analog output (pin 8) to the power supply ground (pin 4). This will cause half of the power supply current to flow through this wire. The voltage drop caused by this current will produce very large errors in the measured output voltage. The longer the cable, the worse the error.

The **set point voltage** (relay trip point) is available on pin 9. This voltage can be measured during a start-up check to be sure that it is adjusted correctly.

CAUTION: Do not short circuit the set point relay terminals to the analog output.

Inductive Loads and Arc Suppression

If the set point relay is used to switch inductive loads, e.g., solenoids, relays, transformers, etc., the arcing of the relay contacts might interfere with controller operation or reduce relay contact life. Therefore an arc suppression network, shown in figure 1, is recommended. The values of the capacitance ***C*** and the resistance ***R*** can be calculated by the equations,

$C = I^2/(1 \times 10^7)$ and $R = E/(I^x)$,

where,

C is in farads

R is in ohms

I is DC or AC_{peak} load current in amperes

E is DC or AC_{peak} source voltage in volts

$x = 1 + (50/E)$.

Note that,

$R_{min} = 0.5$ W and $C_{min} = 1.0 \times 10^{-9}$ F.

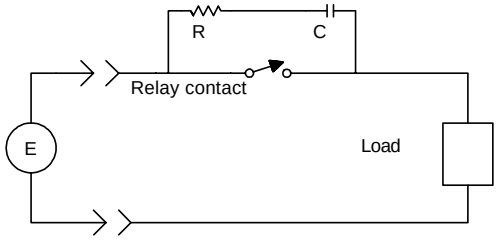


Figure 1: Relay arc suppression network

Adjusting the Set Point

You can adjust the set point relay, to actuate at a particular pressure, using the MODUCELL®ís built-in potentiometer.

To adjust the set point relay to a particular pressure, use the graph on page 10 or the table on page 11 to find the corresponding voltage.

Attach a digital voltmeter to the tip jacks on the side of the MODUCELL® shown in figure 2. While monitoring the voltage at the tip jacks, adjust the potentiometer next to the tip jacks until the indicated voltage matches that of the graph or table for the relay activation pressure.

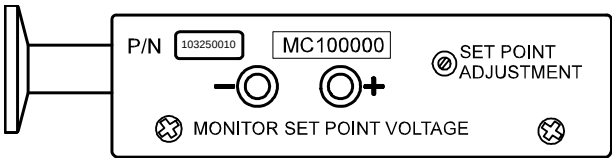


Figure 2

As the measured pressure falls below the set point value, the relay contacts labeled normally open will close, the contacts labeled normally closed will open, and the LED, shown in figure 3, will light.

As the measured pressure rises above the set point value, the relay contacts labeled normally open will open, the contacts labeled normally closed will close, and the LED will no longer light.

Power or sensor failure causes the relay to de-energize, creating the same condition as when the pressure is above the set point.

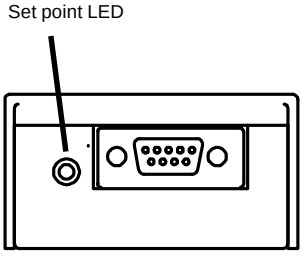


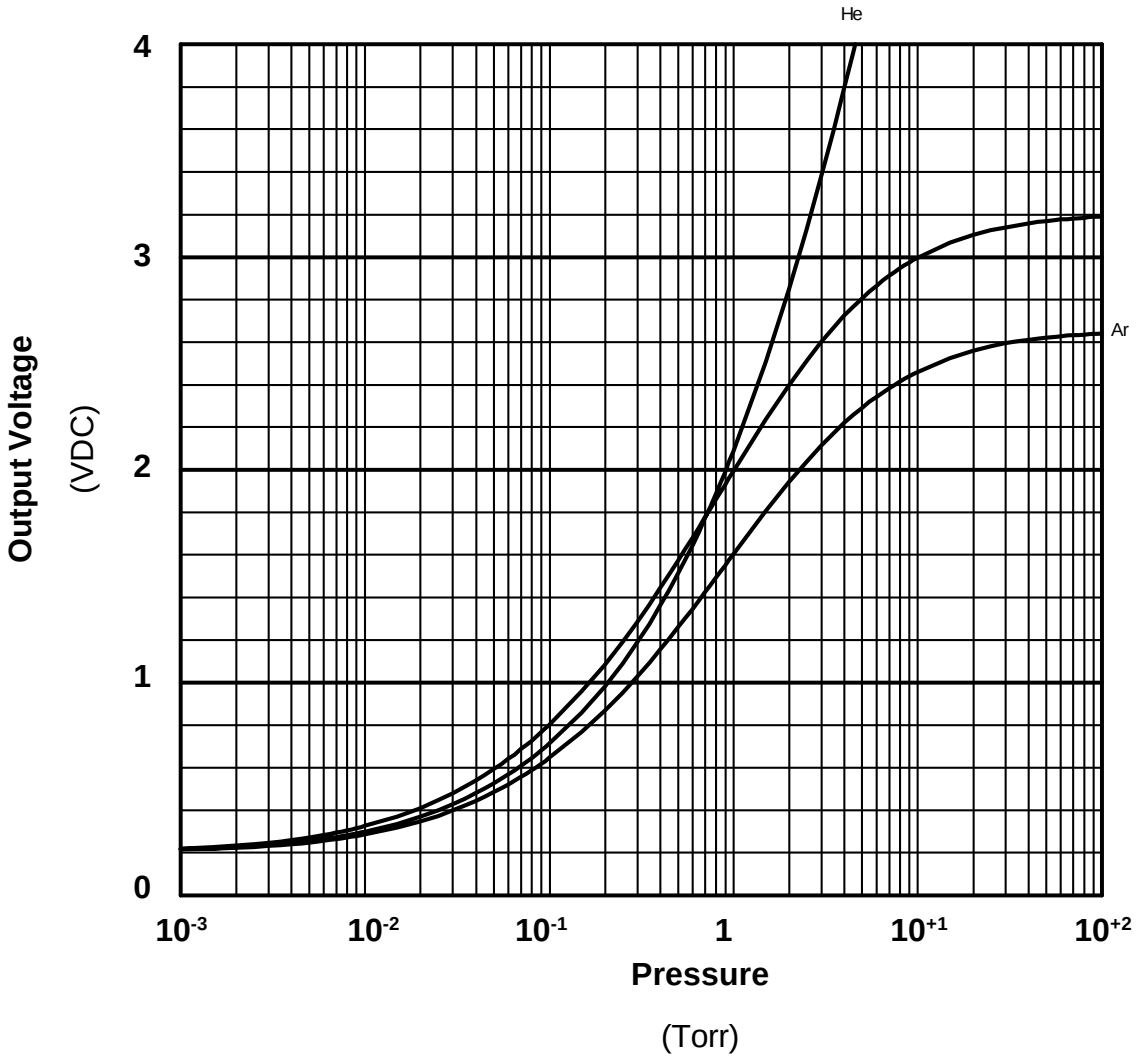
Figure 3

Measuring Pressure with the MODUCELL®

To measure gas pressure with the Series 325 MODUCELL®; refer to either the graph below showing the voltage output as a function of pressure for nitrogen, argon, or helium; the data table opposite which gives the same information; or the equations on pages 13 and 14.

To use the graph or the table to read the pressure, measure the MODUCELL® output voltage with a digital voltmeter or an A/D converter and computer combination.

☞ **When using the graph, remember that the pressure scale is logarithmic, and the voltage scale is linear. Equal increments of distance along the pressure scale do not correspond to equal pressure changes.**



MODUCELL Output Voltage vs. Pressure

Torr	Pascal	Voltage			Torr	Pascal	Voltage		
		Nitrogen	Argon	Helium			Nitrogen	Argon	Helium
0.0010	0.1330	0.2209	0.2158	0.2174	0.70	93.1	1.7744	1.4234	1.7686
0.0013	0.1663	0.2246	0.2181	0.2202	0.80	106	1.8564	1.4906	1.8820
0.0015	0.1995	0.2281	0.2204	0.2229	0.90	119	1.9288	1.5503	1.9875
0.0018	0.2328	0.2316	0.2226	0.2256	1.00	133	1.9935	1.6037	2.0863
0.0020	0.2660	0.2351	0.2248	0.2282	1.50	199	2.2364	1.8059	2.5072
0.0025	0.3325	0.2418	0.2292	0.2334	2.00	266	2.3975	1.9415	2.8456
0.0030	0.3990	0.2484	0.2335	0.2385	2.50	332	2.5130	2.0397	3.1305
0.0040	0.5320	0.2610	0.2419	0.2483	3.00	399	2.6002	2.1142	3.3768
0.0050	0.6650	0.2730	0.2499	0.2577	4.00	532	2.7233	2.2202	3.7876
0.0060	0.7980	0.2844	0.2577	0.2668	5.00	665	2.8064	2.2921	4.1213
0.0070	0.9310	0.2954	0.2652	0.2756	6.00	798	2.8663	2.3443	4.4007
0.0080	1.0640	0.3060	0.2726	0.2841	7.00	931	2.9115	2.3838	4.6395
0.0090	1.1970	0.3162	0.2797	0.2923	8.00	1064	2.9469	2.4149	4.8469
0.0100	1.3300	0.3260	0.2866	0.3003	9.00	1197	2.9754	2.4399	5.0292
0.0125	1.6625	0.3494	0.3032	0.3194	9.50	1263	2.9876	2.4507	5.1124
0.0150	1.9950	0.3713	0.3189	0.3374	10.0	1330	2.9988	2.4605	5.1910
0.0175	2.3275	0.3918	0.3338	0.3544	20.0	2660	3.1052	2.5602	6.1836
0.0200	2.6600	0.4112	0.3480	0.3706	30.0	3990	3.1415	2.5964	6.6695
0.0250	3.3250	0.4474	0.3748	0.4011	40.0	5320	3.1597	2.6127	6.9607
0.0300	3.9900	0.4806	0.3995	0.4293	50.0	6650	3.1707	2.6227	7.1553
0.0400	5.3200	0.5405	0.4446	0.4807	60.0	7980	3.1781	2.6295	7.2947
0.0500	6.6500	0.5936	0.4851	0.5269	70.0	9310	3.1834	2.6344	7.3995
0.0600	7.9800	0.6418	0.5220	0.5693	80.0	10640	3.1874	2.6380	7.4813
0.0700	9.3100	0.6861	0.5561	0.6086	90.0	11970	3.1906	2.6409	7.5469
0.0800	10.640	0.7271	0.5879	0.6454	100	13300	3.1931	2.6433	7.6007
0.0900	11.970	0.7656	0.6177	0.6802	500	66500	3.2165	2.6647	
0.1000	13.300	0.8017	0.6458	0.7132	750	99750	3.2217	2.6696	
0.1250	16.625	0.8841	0.7102	0.7894	1000	133,000	3.2261	2.6737	
0.1500	19.950	0.9573	0.7677	0.8585					
0.1750	23.275	1.0234	0.8198	0.9222					
0.2000	26.600	1.0839	0.8676	0.9815					
0.2500	33.300	1.1913	0.9530	1.0897					
0.30	39.9	1.2850	1.0277	1.1874					
0.40	53.2	1.4424	1.1540	1.3599					
0.50	66.5	1.5715	1.2583	1.5106					
0.60	79.8	1.6805	1.3468	1.6456					

Using the MODUCELL® with a Gas Other than Air or Nitrogen

Before using the MODUCELL® to measure pressure of gases other than air or nitrogen, you should read and understand this section. To answer further questions, contact the Customer Service Department of HP™ Products at 303-449-9861.

The MODUCELL® is designed to give voltage output according to the graph on page 10 or the table on page 11 for air or nitrogen. If the MODUCELL® is used to read pressure of gases with poorer heat transfer properties than nitrogen, the true system pressure may be much higher than indicated. ***This reading error could lead to a dangerous overpressure.***

WARNING: A system which is backfilled from a pressurized gas source should have a safety device installed, such as a burst disc.

Nitrogen Equivalent Pressure and Voltage

The thermal loss from a heated sensor element is a function of the transporting gas (see page A.1, **Theory of the Thermal Conductivity Gauge**.) Since the MODUCELL® is such a sensor, the voltage output depends upon the gas being measured.

Using the voltage and pressure data in the graph on page 10 or the table on page 11, the MODUCELL® output can be read as pressure using an A/D converter and computer. However, when used with gases other than nitrogen, the system would then read nitrogen equivalent pressure. When a Sensor is set up to read pressure for nitrogen but is used with the gases helium or argon, the data in the graph and table can be used to interpret the readings as true pressure.

Calibrating for Gases Not Shown in the Graph or Table

To determine the voltage/pressure relationship for gases which are not shown in the graph or table, you might need to calibrate the MODUCELL® for this gas. This calibration requires a gas type independent gauge such as a capacitance manometer to act as the calibration standard. A curve like that of page 10 can be generated and used as described on page 11.

Detecting Leaks in the System

The MODUCELL® allows the Piraniís inherent gas type sensitivity to be used to detect leaks. A gas different from the system gas entering through a leak will change the thermal energy transfer. Maximum sensitivity is achieved by using a probe gas with a molecular weight much different than the system gas. Note from the E_{gas} equation, in Appendix C, that lighter gases provide increased energy transport while heavy gases reduce the thermal transfer. The MODUCELL® is sensitive to leak probe gases either heavier or lighter than the system gas.

Using the MODUCELL® with a Computer

The MODUCELL® is designed to operate in highly automated systems, especially those that are controlled by digital computers. It is compatible with many different computers, interfaces, and software programs. This section only illustrates some possibilities for the MODUCELL®ís use with computers.

Analog-to-Digital Converter

In order to take full advantage of MODUCELL®ís capabilities, an A/D converter should be used with an input voltage span of 0 to 5 V. The A/D conversion rate should be at least 6 Hz (150 msec conversion time). A resolution of 12 bits is needed, corresponding to 1.22 mV per bit. The A/D converter must have a differential input.

Equations for Converting Voltage to Pressure

The two following equations convert a MODUCELL® voltage reading in volts to a pressure reading in Torr. The voltage must be within the domain of the equation or an incorrect pressure reading will result.

$$P = \left[\frac{a}{\frac{b}{V^2 - V_0^2} - 1} \right]^{1/c}$$

Nitrogen
The domain is $0.21 < V < 3.0$,
where $a = 1.6578$, $b = 10.45$, $c = 0.9954$, and $V_0 = 0.2057$.

Argon
The domain is $0.21 < V < 2.6$,
where $a = 1.81$, $b = 7.107$, $c = 0.997$, and $V_0 = 0.2063$.

Helium
The domain is $0.21 < V < 7.7$,
where $a = 14.394$, $b = 66.35$, $c = 0.992$, and $V_0 = 0.2059$.

$$P = \frac{(V-d) + \div\sqrt{(V-d)^2 - 4fg}}{2f}$$

Nitrogen
The domain is $V > 3.0$,
where $d = 3.2133$, $f = 1.501 \times 10^{-5}$, and $g = -2.168$.

Argon
The domain is $V > 2.6$,
where $d = 2.6617$, $f = 1.4 \times 10^{-5}$, and $g = -1.983$.

Maintaining the MODUCELL®

Cleaning the MODUCELL® Case and Sensor Tube

The finish on the MODUCELL® case is designed to resist many laboratory solvents, but it should be cleaned with water or alcohol.

The tube can be contaminated by roughing pump oils and other fluids condensing or decomposing on the heated filament. Such contamination changes the emissivity of the filament, and the different emissivity can cause the calibration to change, especially with low pressure.

However, ***it is not advisable to clean the sensor tube***. Trying to clean the tube would very likely either deform or break the filament, and the deformed filament would then cause additional error from a shift in the sensor's output.

If the sensor tube has become contaminated, it is best to replace it following the procedure given on page 16.

Troubleshooting

A troubleshooting chart for the MODUCELL® follows. With this guide, you should be able to locate and remedy the cause of a fault. The problems listed here might occur on the system assembly level. Other faults are usually not serviceable by the user, and the faulty unit should be returned to HP™ to be repaired.

WARNING: Ground yourself before handling the circuit board or any of its components, and do not place the circuit board or components on an insulating surface. The circuit board of the MODUCELL® has parts which could be damaged by electrostatic discharge.

Troubleshooting Chart

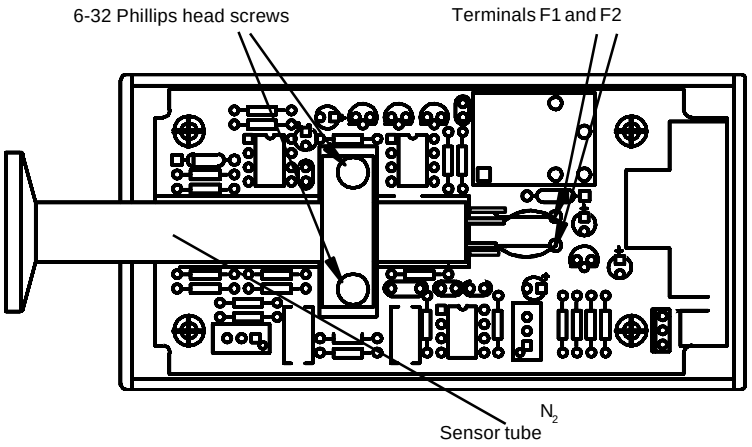
Symptom	Possible Cause	Remedy
Pressure readings are too high or low.	1. Sensor may be dirty or contaminated.	1. Test and replace if necessary. Refer to page 16.
No analog output voltage, and no set point voltage.	1. D-sub is disconnected. 2. Power supply turned off.	1. Connect D-sub. 2. Turn power on.
No analog output voltage, but set point voltage OK.	1. Broken or shorted filament. 2. Analog output shorted to ground.	1. Test and replace if necessary. Refer to page 16. 2. Check cable connection at the D-Sub connector.
Set point relay will not operate.	1. Set point voltage incorrectly set. 2. Broken or shorted filament. 3. Pin 7 of D-sub not connected to ground at power supply.	1. Check your set point. 2. Test and replace if necessary. Refer to page 16. 3. Check any external switches which may be controlling this line.

Testing the Sensor Tube

You can test the function of the MODUCELL® Sensor tube even if improper cleaning or rough handling has damaged the tube slightly and affected calibration.

1. Disconnect the lead from the D-sub connector.

2. Remove the four Phillips head screws from the MODUCELL® sides, and remove the cover.



Checking resistance

3. Check the resistance from terminal F1 to F2, the wires leading to the Sensor tube as shown at right. The resistance reading should be approximately 31 W. If the reading is approximately 340 W, the tube filament is broken or burned out.

4. Check the resistance from F1 to the tube body and from F2 to the tube body. With the D-sub disconnected, both readings should show a resistance of more than 20 MW. If the reading is lower, the tube might have an internal short which could be caused by either a damaged filament or some type of contamination on the inside of the tube. In either case, the defect requires that you replace the Sensor tube. The following section gives the procedure for doing so.

Replacing the Sensor Tube

Disassembling the MODUCELL®

1. Remove the four Phillips head screws that secure the cover on the sides.

2. With a low wattage soldering iron, desolder the two wires that connect the tube to terminals F1 and F2. (See the figure above.)

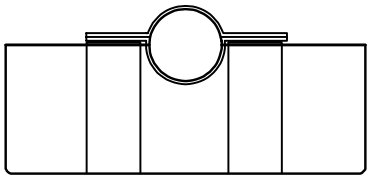
3. Remove the two 6-32 Phillips head screws that hold the tube in place.

4. Remove the tube by lifting it straight up.

Assembling the MODUCELL®

1. Install a new tube. Place a small dab of silicone heat sink compound between the thermistor (see the figure on the following page) and tube, and then place it in position.

☞ **The mounting bracket is slightly off-center. Be sure the tube is oriented so that its center line is offset toward the board. The figure at left shows this when looking in at the MODUCELL® toward the pins from the top view.**



End-on tube view

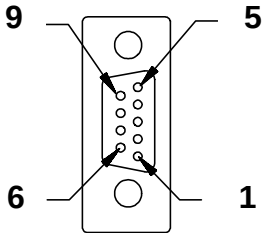
2. Install the two 6-32 Phillips head screws to secure the tube in place.

3. Solder the two wires from the tube to F1 and F2. Clip off any excess wire. Be sure the clippings do not fall into the enclosure.

4. Calibrate the new Sensor tube following the four steps below.

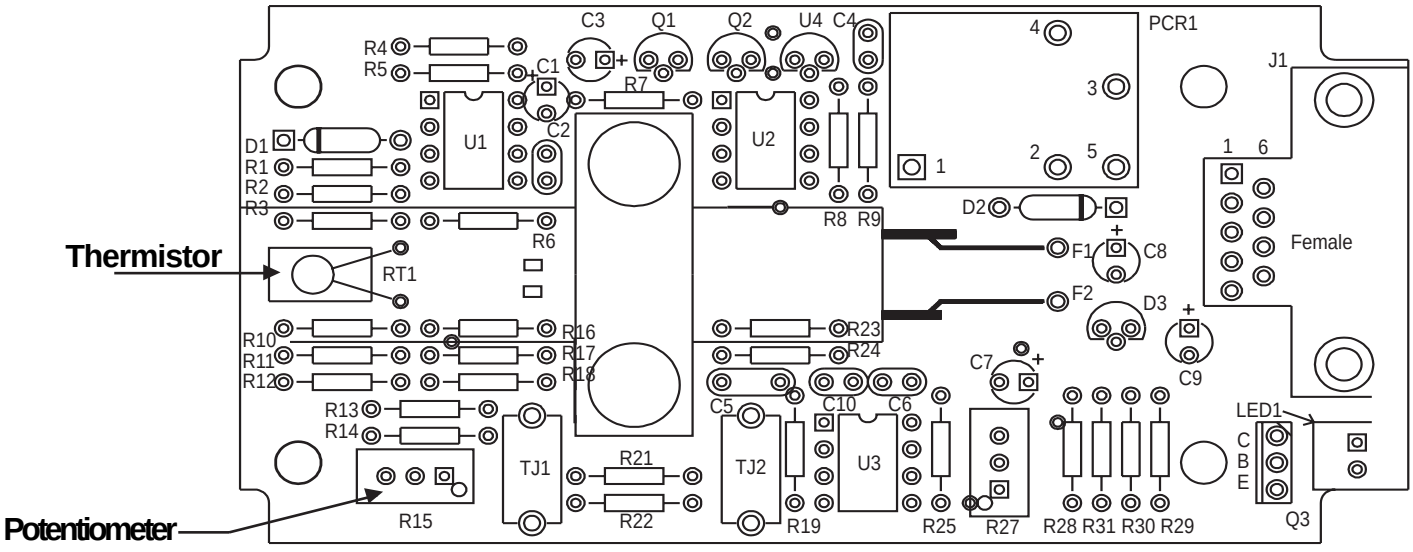
a. Position the MODUCELL® so that the tube axis is vertical.
b. Operate the unit for at least 20 minutes at atmospheric pressure (nitrogen or air).
c. Attach a voltmeter between pins 5 and 8 of the D-sub connector, (+) to pin 5 and (-) to pin 8.
d. Adjust the potentiometer, R15, (See the figure below) for a voltage reading of 3.222 V.

5. Install the cover and four Phillips head screws.



Female, 9-pin

D-sub connector



Product Warranty

Extent of the Warranty
MKS Instruments, Inc., HPS™ Products, Inc., warrants the HPS™ Products Series 325 MODUCELL® Pirani Vacuum Sensor/Transducer and its accessories to be free from defects in materials and workmanship for one (1) year from the date of shipment by HPS™ or authorized representative to the original purchaser (PURCHASER). Any product or parts of the product repaired or replaced by HPS™ under this warranty are warranted only for the remaining unexpired part of its one (1) year original warranty period. After expiration of the applicable warranty period, the PURCHASER shall be charged HPS™í current prices for parts and labor, plus any transportation for any repairs or replacement.
ALL EXPRESS AND IMPLIED WARRANTIES, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO THE WARRANTY PERIOD. NO WARRANTIES, EXPRESS OR IMPLIED, WILL APPLY AFTER THIS PERIOD.

Warranty Service
The obligations of HPS™ under this warranty shall be at its option: (1) to repair, replace, or adjust the product so that it meets applicable product specifications published by HPTM or (2) to refund the purchase price.

What Is Not Covered
The product is subject to above terms only if located in the country of the seller from whom the product was purchased. The above warranties do not apply to:
I. Damages or malfunctions due to failure to provide reasonable and necessary maintenance in accordance with HPS™ operating instructions.
II. Damages or malfunctions due to chemical or electrolytic influences or use of the product in working environments outside the specification.
III. Fuses and all expendable items which by their nature or limited lifetime may not function for a year. If such items fail to give reasonable service for a reasonable period of time within the warranty period of the product; they will, at the option of HPS™, be repaired or replaced.
IV. Defects or damages caused by modifications and repairs made by the original PURCHASER or third parties not authorized in the manual.

Condition of Returned Products
HPS™ will not accept for repair, replacement, or credit any product which is asserted to be defective by the PURCHASER, or any product for which paid or unpaid service is desired, if the product is contaminated with potentially corrosive, reactive, harmful, or radioactive materials, gases, or chemicals.
When products are used with toxic chemicals, or in an atmosphere that is dangerous to the health of humans, or is environmentally unsafe, it is the responsibility of the PURCHASER to have the product cleaned by an independent agency skilled and approved in the handling and cleaning of contaminated materials before the product will be accepted by HPS™ for repair and/or replacement.
In the course of implementing this policy, HPS™ Customer Service Personnel may inquire of the PURCHASER whether the product has been contaminated with or exposed to potentially corrosive, reactive, harmful, or radioactive materials, gases, or chemicals when the PURCHASER requests a return authorization. Notwithstanding such inquiries, it is the responsibility of the PURCHASER to ensure that no products are returned to HPS™ which have been contaminated in the aforementioned manner.

Other Rights and Remedies
I. These remedies are exclusive. HPS™ SHALL NOT BE LIABLE FOR CONSEQUENTIAL DAMAGES, FOR ANTICIPATED OR LOST PROFITS, INCIDENTAL DAMAGES OR LOSS OF TIME, OR OTHER LOSSES INCURRED BY THE PURCHASER OR BY ANY THIRD PARTY IN CONNECTION WITH THE PRODUCT COVERED BY THIS WARRANTY, OR OTHERWISE. Some states do not allow exclusion or limitation of incidental or consequential damage or do not allow the limitation on how long an implied warranty lasts. If such laws apply, the limitations or exclusions expressed herein may not apply to PURCHASER.
II. Unless otherwise explicitly agreed in writing, it is understood that these are the only written warranties given by HPS™. Any statements made by any persons, including representatives of HPS™, which are inconsistent or in conflict with the terms of the warranty shall not be binding on HPS™ unless reduced to writing and approved by an authorized officer of HPS™.
III. This warranty gives PURCHASER specific legal rights, and PURCHASER may also have other rights which vary from state to state.
IV. For HPS™ products sold outside of the U.S., contact your MKS representative for warranty information and service.

Warranty Performance
To obtain warranty satisfaction, contact the following: MKS Instruments, Inc., HPS™ Products Inc., 5330 Sterling Drive, Boulder, CO 80301, USA, at phone number (303) 449-9861. You may be required to present proof of original purchase.

Notes

Appendix A: How the MODUCELL® Works

The MODUCELL® is a heat-loss manometer which infers the pressure of a gas by measuring thermal loss from a heated wire.

Theory of the Thermal Conductivity Gauge

A hot wire suspended from supports in a partial vacuum loses thermal energy in three ways:

- thermal energy transport, which is pressure dependent,
- end loss to the supports, and
- radiation to surrounding surfaces.

Pirani and thermocouple gauges use the pressure-dependent thermal energy transport from a hot wire to measure pressure. Because the end loss and radiation are constant for a wire at constant temperature, they provide a masking signal which largely determines the low pressure limit of the gauge. Optimizing parameters for the wire length and diameter, thermal emissivity, thermal conductivity, and wire temperature can control these terms but not eliminate them.

A Pirani gauge may be operated at constant current, constant voltage, or constant resistance (equivalent to constant temperature) at the sensor wire. The MODUCELL® is operated at constant temperature to increase high pressure sensitivity. At constant current or voltage, the wire temperature at high pressure is much less than the temperature value at vacuum, reducing the high pressure sensitivity.

See Appendix C for a more detailed discussion of energy transfer and measurement limits.

The MODUCELL® Design Overview

The MODUCELL® uses a wire as one arm of a balanced Wheatstone bridge. The bridge amplifier maintains the sensor wire at a constant temperature, and the amplifier output varies with the energy loss.

Bridge Amplifier
The bridge amplifier, op amp U3a, operates in a balanced bridge configuration to keep the sensor element temperature constant. Thus, the bridge driving voltage from the amplifier is related to the pressure in the gauge.

This bridge driving voltage is buffered by op amp U3b and is then fed to pin 9 of connector J1 and the comparator circuit.

Voltage Reference
Diode D3 and op amp U1a form a precision adjustable reference that is fed to the comparator circuit. Trimpot R27 can be adjusted to the proper voltage to trigger the set point relay at the desired pressure.

Comparator
Op amp U1b is an analog comparator circuit that compares the voltage from the buffer amplifier (pressure signal) to the reference voltage. When the pressure signal falls below the adjusted reference voltage, transistor Q2 is turned on, energizing the set point relay PCR1 and indicator LED1. Resistor R4 then provides a feedback path around op amp U1b, which increases the set point voltage by approximately 5 mV. This hysteresis provides stable operation even though some noise may be present on the buffered pressure signal.

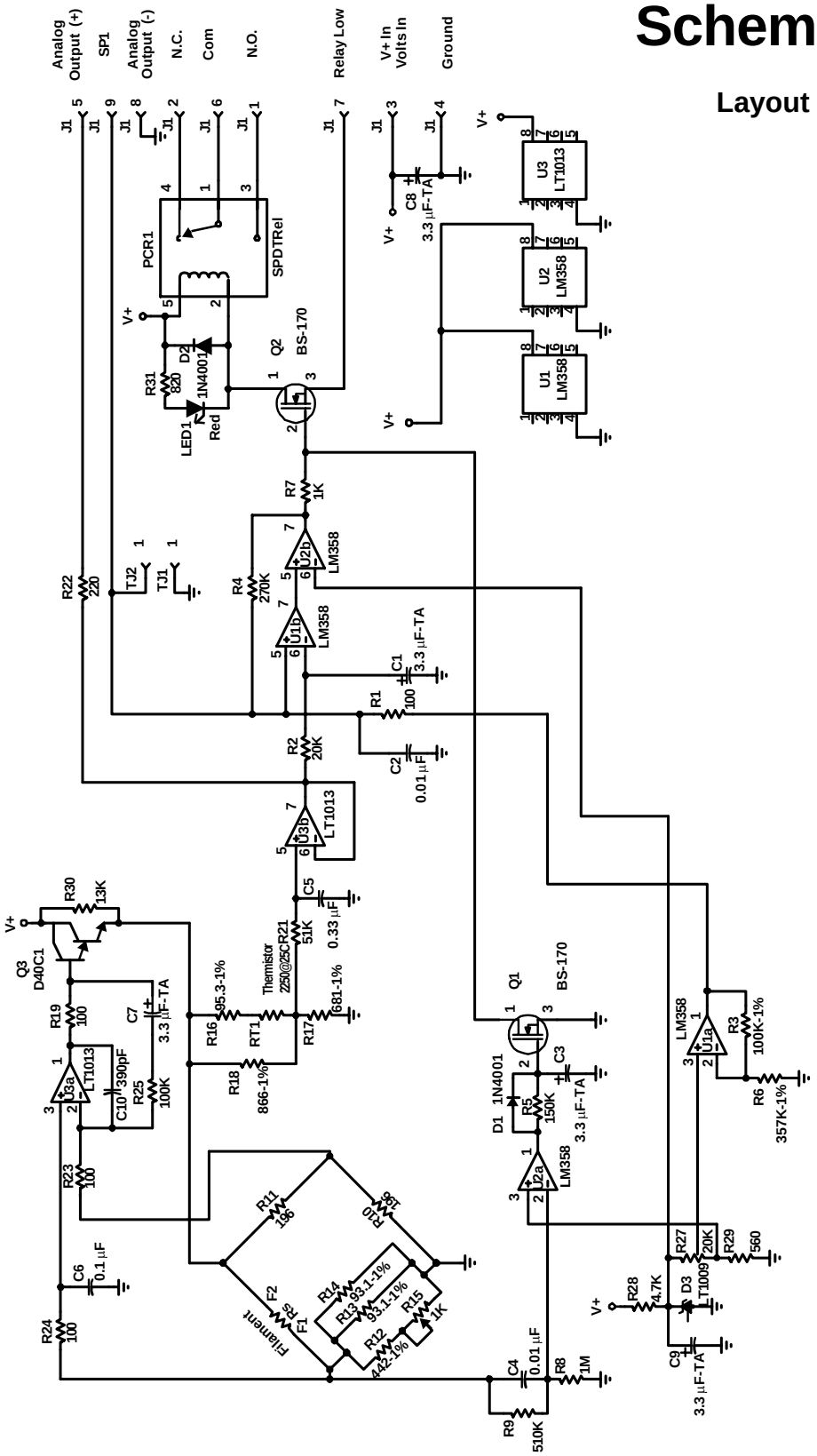
Open Filament Detector
Op amp U2a acts as a comparator that monitors the filament side of the bridge. If the sensor filament breaks, the inverting input of the op amp falls below the 80 mV reference voltage from R29, turning on transistor Q1 which prevents transistor Q2 from turning on. Thus the set point relay will not energize, making the MODUCELL® fail-safe.

Appendix B has a detailed schematic and layout diagram for reference.

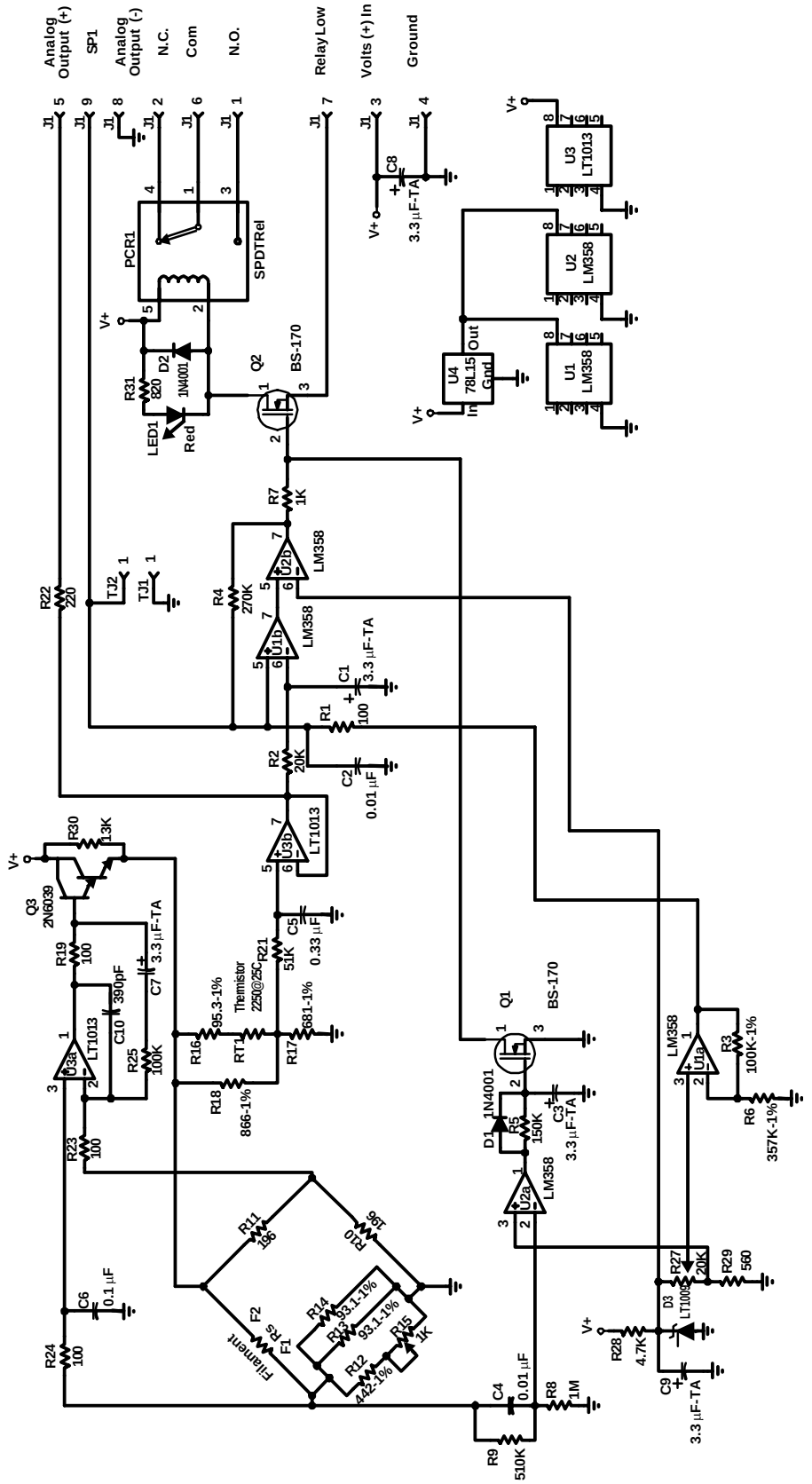
Notes

Appendix B: Electrical Schematics

Layout Diagrams

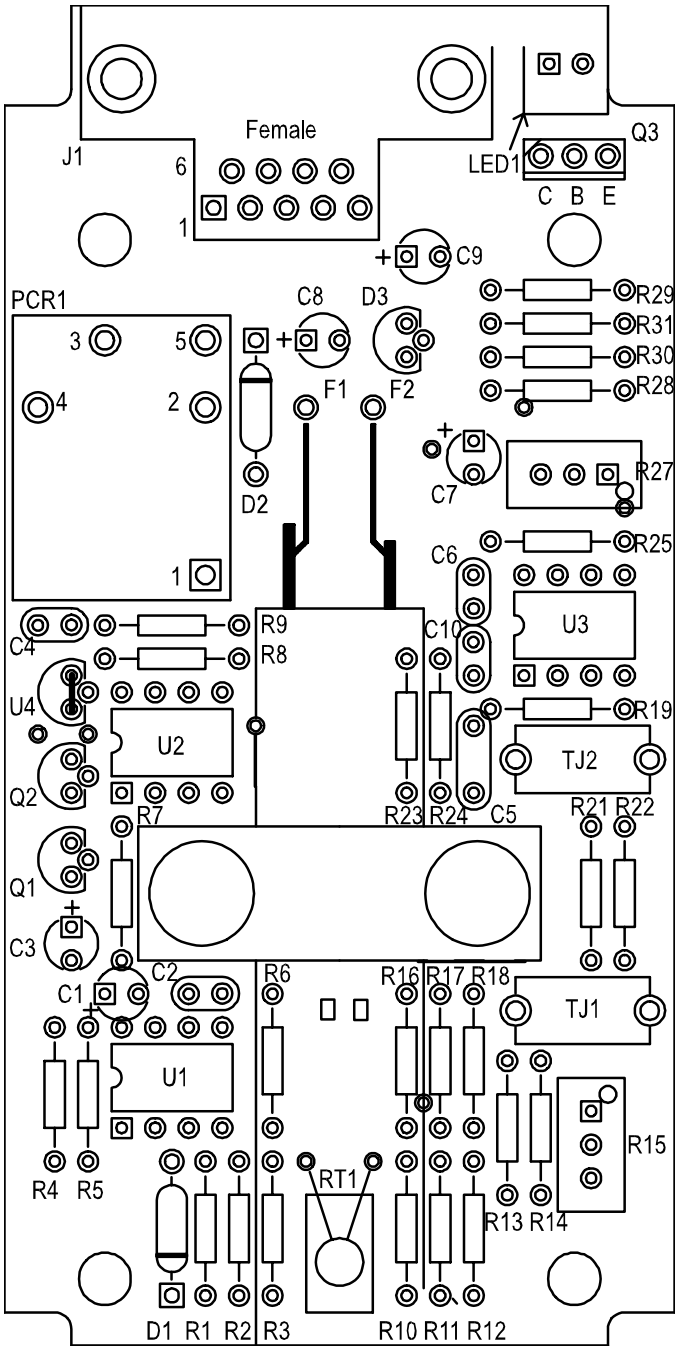


MODUCELL Electrical Schematic: 15V

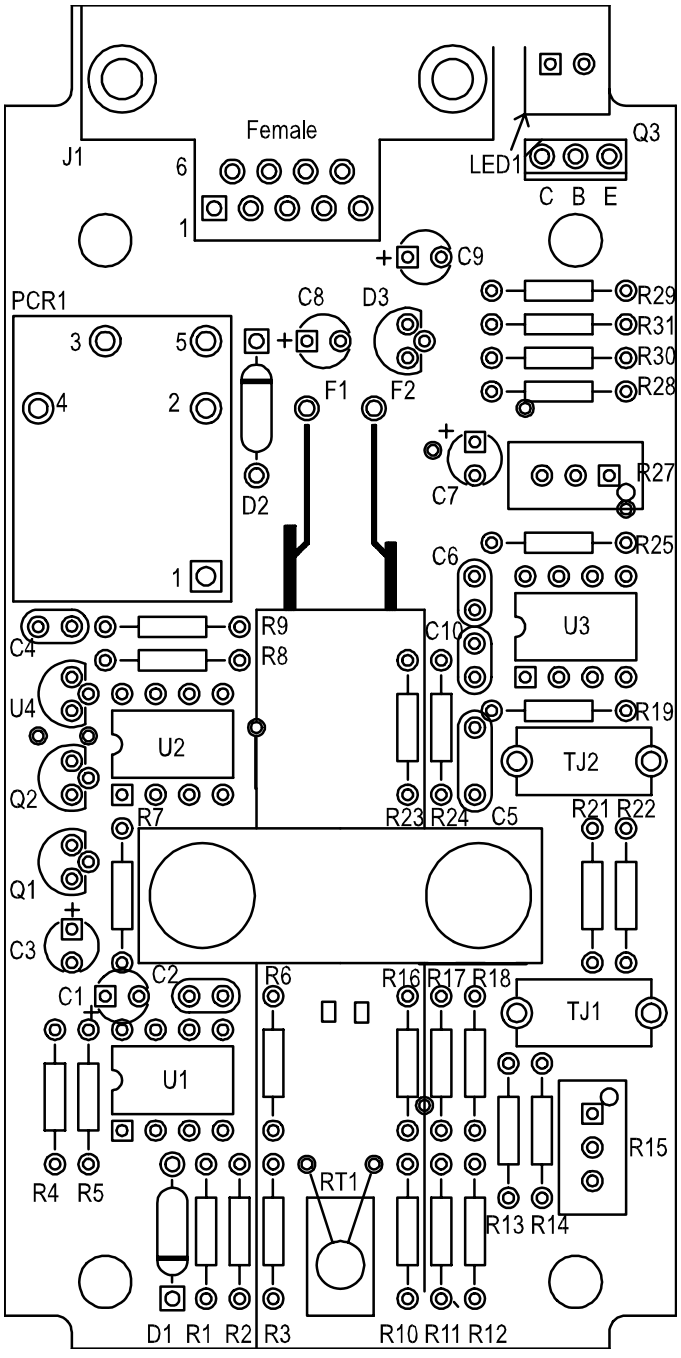


MODUCELL Electrical Schematic: 24V

MODUCELL Circuit Board Layout: 15V



MODUCELL Circuit Board Layout: 24V



Notes

Appendix C: Energy Transfer and Measurement Limits

The Energy Transfer Equation

The mechanism of energy transfer between the wire and the gas in a heat-loss manometer like the MODUCELL® depends upon the pressure range. For pressures below 10^{-1} Torr, it is possible to derive an equation showing a linear relationship between the thermal energy loss to the gas E_{gas} and the pressure P where

$$E_{gas} = \text{const. } a \frac{1\ (\gamma + 1)}{4\ (\gamma - 1)} \left[\frac{(T_w - T_g)}{\sqrt{MT_g}} \right] P$$

and for the particular gas,

- a is the accommodation coefficient,
- g is the ratio of the specific heat at constant pressure to that at constantvolume,
- M is the molecular weight of the gas,
- T_w is the temperature of the wire, and
- T_g is the temperature of the gas.

Measurement Limits

At pressures above 100 Torr for nitrogen, and widely differing values for other gases, the gas acts like an insulating layer. At still higher pressures, and in a large enclosure, convection contributes to energy transport.

The pressure range between 10^{-1} Torr and 100 Torr is a transition region, where the slope of the energy loss curve decreases continuously.

Note that the sum of end and radiation losses is about 10 times the gas transport at a pressure of 10^{-3} Torr. This determines the practical lower limit for thermal conductivity gauges. It is possible to measure lower pressures, but long term stability becomes a serious problem.

From the energy loss equation above, it is clear that the signal from a thermal conductivity gauge is not calculable from first principles but depends upon gas type. Because the energy transfer is dependent upon the rate of molecular collisions with the wire surface and upon the energy absorbed by each molecule, the gas transport is dependent upon the molecular weight, the internal degrees of vibrational freedom of the molecule, and the accommodation coefficient of the gas.

Notes